9-1-2021

Freedom of Will, Physics, and Human Intelligence: An Idea

Miroslav Svitek
Czech Technical University in Prague, svitek@fd.cvut.cz

Vladik Kreinovich
The University of Texas at El Paso, vladik@utep.edu

Nguyen Hoang Phuong
Thang Long University, nhphuong2008@gmail.com

Comments:

Technical Report: UTEP-CS-21-79

Freedom of Will, Physics, and Human Intelligence: An Idea

Miroslav Svítek, Vladik Kreinovich, and Nguyen Hoang Phuong

Abstract Among the main fundamental challenges related to physics and human intelligence are: How can we reconcile the free will with the deterministic character of physical equations? What is the physical meaning of extra spatial dimensions needed to make quantum physics consistent? and Why are we often smarter than brain-simulating neural networks? In this paper, we show that while each of these challenges is difficult to resolve on its own, it may be possible to resolve all three of them if we consider them together. The proposed possible solution is that human reasoning uses the extra spatial dimensions. This may sound weird, but in this paper, we explain that this solution is much more natural than how it sounds at first glance.

1 Three Fundamental Challenges

What is science about? Science studies the world.

Most of the studies cover different objects. Generally speaking, this is what physics is about – be it physics proper, chemistry (and chemical physics), biology (and biophysics), geosciences (and geophysics), astronomy (and astrophysics), etc.

We humans also study ourselves, not just our own biology, but also the way we think and reason.

Miroslav Svítek
Faculty of Transportation Sciences, Czech Technical University in Prague, Konviktska 20
CZ-110 00 Prague 1, Czech Republic, e-mail: svitek@fd.cvut.cz

Vladik Kreinovich
Department of Computer Science, University of Texas at El Paso, 500 W. University
El Paso, TX 79968, USA, e-mail: vladik@utep.edu

Nguyen Hoang Phuong
Division Informatics, Math-Informatics Faculty, Thang Long University, Nghiem Xuan Yem Road
Hoang Mai District, Hanoi, Vietnam, e-mail: nhphuong2008@gmail.com

Fundamental challenges. Science is an evolving body, it has many open problems, many challenges. Every year, new discoveries are made, new challenges appear: how to describe a new phenomenon? how exactly will different observed phenomena evolve? These are all serious challenges, and Nobel prizes are awarded to those who solve them.

In addition to such "usual" scientific challenges, there are also fundamental challenges, challenges that deal not with our ability or inability to predict new phenomena, but rather with some perceived fundamental flaws of the current theories. Let us describe the main such challenges: challenges of physics, challenges arising from the relation between physics and study of human reasoning, and challenges related to the study of human reasoning itself.

Fundamental challenges in physics. To describe these challenges, let us start with physics proper. Let us recall why many physicists are not always completely happy with their theories – even when their theories provide a perfect prediction of the corresponding phenomena.

To a naive mathematician, a physical theory may be nothing else but the corresponding set of equations. However, physicists understand that physics is much more than the set of equations: it involved deep understanding of the related phenomena, an understanding that helps physicists make predictions. A classical example of the need to have something beyond equation is the history of General Relativity. It is known that the great mathematician David Hilbert came up with the same equations as Einstein – he submitted his paper two weeks later than Einstein, so Einstein was first. This is a known historical fact. What may be less known is that even if Hilbert was first, Einstein would still deserve his fame. Indeed:

- All Hilbert did was derive the equations – the system of complex non-linear partial differential equations. Hilbert did not provide any solutions to these equations – they were too complex to solve by known mathematical methods.
- In contrast, Einstein not only proposed the equations, he also provided some approximate solutions, solutions that were experimentally tested in a few years.

Einstein came up with these solution not because he was a better mathematician, no, he came up with these solutions because he had a good physical intuition that enabled him to understand which terms in the original nonlinear system could be safely ignored – and this led to a solvable approximation.

Another Einstein-related example (borrowed from [13]) is that when a guide who showed, to Einstein's wife, a state-of-the-art computer, explained that this computer was busy finding the structure of the Universe as a whole – she replied that her husband did the related calculations on the back of an envelope.

From this viewpoint, it is not enough to come up with mathematical formulas for prediction, we also need to gain a good intuitive understanding of the corresponding phenomena, an intuition that would enable us to provide experimental confirmations of the resulting theory. Whenever such an understanding is missing, we have a fundamental challenge. And in theoretical physics, there is indeed such a challenge.

Specific challenge. This challenge is related to the fact that while current equations of quantum field theory predict many future events with very high accuracy, there is still an important challenge – if we write down seemingly natural equations of quantum field theory in our usual 4-dimensional space-time, then, for some future values, we get meaningless infinite values. In many cases, physicists came up with several tricks to avoid such infinities. A fundamental solution to this problem was found by string theory, according to which a consistent quantum theory is only possible in space-times of dimension 11 and higher; see, e.g., [11, 22, 26].

This is an exciting and useful mathematical result, but from the physical viewpoint, this solution is not fully satisfactory, since:

- in contract to the usual 4 dimensions that have precise physical meaning,
- the additional 7 or more dimensions largely remain purely mathematical constructions.

What is the physical meaning of these extra dimensions is not clear.

Another path to extra dimensions comes from foundations of quantum physics. One of the main interpretations of the stochastic character of quantum predictions is that there are actually many possible worlds, and when we perform an experiment, we branch – with appropriate probabilities – into one of these possible worlds. From the fundamental viewpoint, it is the same idea as extra dimensions – namely, the world we observe is a tiny part of the larger world. In this case, additional dimensions make some physical sense – they correspond to possible worlds.

However, in this case too, all we observe is *one* possible world, a tiny portion of the whole multi-world universe. And physicists understandably do not like theories that heavily rely on unobservable quantities, this sounds too much like speculations rather than physics.

Researchers have been trying to find some physical meaning of the extra dimensions. For example, the Nobelist Andrei Sakharov – best known for his human rights activities – conjectured, in [23], that, in contrast to usual many-world interpretation in which possible worlds do not interact, there is actual interaction between possible worlds, and that, e.g., strong interaction between protons and neutrons can be explained in this way. This idea sounded – and still sounds – promising, it was even cited in a textbook on gravitation [16], but no experimental confirmation of such interaction was found.

Fundamental challenges about the relation between physics and study of human reasoning. Modern physics is largely deterministic. According to physics' equations, once we know the initial state of the Universe – or of any closed system – this initial state uniquely determines the future state at all future moments of time.

To be more precise, before quantum physics, the world's description was fully deterministic in this sense. Quantum physics added an additional level of uncertainty: namely, according to quantum physics, the state does not uniquely predict results of future measurements, but it does uniquely predict the probabilities of different future measurement results; see, e.g., [7, 26].

Many equations of physics have been confirmed on multiple examples with high accuracy. However, their deterministic nature contradicts our intuitive understanding that we have freedom of will, that we can make decisions and select different alternatives – thus changing the future state of our environment (and therefore the state of the Universe); see, e.g., see, e.g., [2, 3, 4, 5, 8, 9, 12, 14, 21, 24, 25, 27, 28, 29, 30] and references therein.

Some people are so much convinced by physics that they start really believing that freedom of will is an illusion [1] – for example, Einstein, who could not swim, nevertheless liked to go yachting on his own, arguing that whether he drowns or not is pre-determined by the initial state of the Universe and does not depend on his decisions; see, e.g., [13]. To most people, however, this sounds weird, they believe that we can change the state of the universe.

But how can we reconcile this belief with physics? The world consists of elementary particles. So, the fact that we change the state of the Universe means that we can somehow, by our sheer will, change the state of some of these particles. Many experiments tried to see if such "telekinesis" – using willpower to change the state of the material objects – is indeed possible, but no such ability was found. No matter how much people tried, they were never able to affect the results of physical experiments.

Challenges related to the study of human reasoning. We have come a long way towards understanding how we reason and how we think. We know, in many detail, how signals are processes in our brains: the signals go from a neuron to a neuron, and these signals are processed by these neurons in a (largely) known way.

This knowledge has led to development of artificial devices that simulate this activity – artificial neural networks. Current deep neural networks indeed have spectacular successes; see, e.g., [10].

However, in many aspects, these networks are still not as smart as we are – and not as smart as we have hoped them to be. For example, while deep networks perform very well on tasks with which previous computer programs had trouble, such as distinguishing between cats and dogs, it is known that a small change in the input – a change that would not affect human decisions – can lead a neural network to a completely erroneous classification; see, e.g., [10].

The fact that the drastic increase in the number of neurons does not make the artificial neural networks as close to our intelligence abilities as we hoped – this fact has been recognized by many researchers, many of whom speculated that the human brain uses physical phenomena beyond the usual processing of electric signals. For example, Roger Penrose famously conjectured, in [20], that the human brain is actually involved in quantum computing – and it is known that quantum computing can indeed drastically increase the system's computational abilities; see, e.g., [18]. This was a very interesting and very promising hypothesis – but no evidence of such quantum activity was found, so this hypothesis was abandoned.

As a result, the challenge remains: why are we so smart – to be more precise, why are our brains much smarter than similar-size artificial neural networks that try their best to emulate how our brains work?

Let us summarize. In modern science, in addition to the “usual” challenges – how to predict future phenomena, how to explain the observed phenomena – there are several fundamental challenges, and we have mentioned three such challenges:

- What is the physical meaning of extra spatial dimensions?
- How to reconcile freedom of will and physics?
- How to explain that we are often much smarter than computer models that seem to adequate simulate our brains?

What we do in this paper. In this paper, we show that all these three challenges can be resolved if we view them together.

2 How We Can Solve These Challenges: An Idea

Let us start with the first challenge. Let us start our analysis with the very first challenge: how to explain the physical meaning of additional spatial dimensions? What are the physical (= observable) consequences of the existence of possible worlds – worlds that exist in parallel to our world?

Natural idea. To answer this physical challenge, let us take the second challenge into account – the existence of free will. Intuitively, free will means that which possible world we get into is not just randomly determined – *we* can select to which of the possible worlds we move. In other words, free will means that we can move in the space of possible worlds – i.e., that we can move in the extra spatial dimensions corresponding to these possible worlds.

If we assume that we humans can indeed move in these extra dimensions, this provides the desired physical meaning to these dimensions. Namely, there are objects that function in these extra dimensions and that move in these extra dimensions – and we ourselves are these objects.

This also helps with the second challenge. This idea also explain why, in spite of the fact that our will cannot change anything in the 3-D world, we can (and do) make changes by our choices: while we *cannot* change anything in the usual 3-D world, what we *can* do is move between possible worlds – in other words, our free will can select in which of the possible worlds we will be in the future.

This also helps with the third challenge. Let us show that the possibility to move in extra dimensions can also provide a solution to the third challenge – namely, as we will show, the possibility to move in additional spatial dimensions increases our computational abilities – i.e., in particular, our abilities to process information and to reason.

But how do additional dimensions contribute to computational abilities? To answer this question, let us recall that in computer science, the complexity of an algorithm is usually measured by the time $T_{\rm seq}$ needed to perform this algorithm step-by-step on a sequential computer. For many problems, this is too long – for example, if it takes a week to predict tomorrow's weather, then this prediction algorithm is useless, since we will observe tomorrow's weather way before the algorithm finishes its computations. In such situations, it is desirable to speed up computations.

How can we speed up computations? If a human being has a time-consuming task – e.g., cleaning all the offices in a building before an inspection – and it would take too long for one person to clean all the rooms, a natural idea is to have several people cleaning rooms at the same time. Similarly, if some computational task takes too long a time for a single processor, a reasonable idea is to have several processors working in parallel. At first glance, it may seem that the more processors we add, the faster the computation can be. However, in reality, there is a limit to the possible speedup – a limit caused by the fact that, according to modern physics, all the speeds are limited by the speed of light c. Let us show – following [17] – how this limits the computation speed.

Suppose that we have a computational device in which several processes work in parallel, and that this device finishes its computations in time $T_{\rm par}$. In other words, $T_{\rm par}$ is the time between the moment when we present the task to this device and the moment when the device presents us the result. During this time, if any processor is involved in this computation, some signal must reach this processor, and some results from this processor must eventually find their way back to us. So, if this processor is located at some distance r from us, the signal must travel at least a distance $2r$. During the time $T_{\rm par}$, the largest distance that can be covered is the distance $c\cdot T_{\rm par}$. Thus, we must have $2r \le c\cdot T_{\rm par}$ and hence, $r \le (c/2)\cdot T_{\rm par}$. So, all processors that affect the computation result must be located within the sphere of radius $R \stackrel{\rm def}{=} (c/2)\cdot T_{\rm par}$. In the usual 3-D space, the volume V of this inside-sphere region is equal to

$$V = \frac{4}{3}\cdot\pi\cdot R^3 = \frac{4}{3}\cdot\pi\cdot\left(\frac{c}{2}\right)^3\cdot T^3_{\rm par}.$$

Let us denote by ΔV the size of the smallest possible processor, and by $N_{\rm proc}$ the number of processors involved in the computation. Overall, these processors occupy at least the volume $N_{\rm proc}\cdot\Delta V$. This volume cannot exceed the overall volume V: $N_{\rm proc}\cdot\Delta \le V$, so we get an upper bound on the possible number of processors:

$$N_{\rm proc} \le \frac{V}{\Delta V} = C\cdot T^3_{\rm seq},\ \text{where}\ C \stackrel{\rm def}{=} \frac{1}{\Delta V}\cdot\frac{4}{3}\cdot\pi\cdot\left(\frac{c}{2}\right)^3.$$

Computations on a parallel computer can be simulated on a sequential computer: for each moment of time, we simulate what the first processor does, then what the second processor does, etc. In this simulation, one time period of the parallel computer is simulated in $N_{\rm proc}$ time periods. Thus, the overall computation time increases by a factor of $N_{\rm proc}$. As a result, we perform the same computations on a sequential computer in time

$$N_{\rm proc}\cdot T_{\rm par} \le C\cdot T^3_{\rm par}\cdot T_{\rm par} = C\cdot T^4_{\rm par}.$$

So, if we denote by $T_{\rm seq}$, the smallest possible time needed to solve the corresponding problem on a sequential computer, then we get

$$T_{\rm seq} \le C \cdot T_{\rm par}^4.$$

From this inequality, we can conclude that

$$T_{\rm par} \ge C^{-1/4} \cdot T_{\rm seq}^{1/4}.$$

In other words, we can speed up computations, but there is a limit to this speedup. The main reason why we need speedup is that many problems are NP-hard; see, e.g., [15, 19]. Unless it turned out that P = NP, solving such problems requires, in the worst case, exponential time $\approx 2^n$, where n is the size of the input. For reasonable-size inputs $n = 300$ and $n = 600$, we will need, correspondingly, $2^{300} \approx 10^{100}$ and $2^{600} \approx 10^{200}$ steps – which would take much larger than the lifetime of the Universe. Let us see what happens if we parallelize these problems.

- If the lower limit for sequential computer is $2^{300} \approx 10^{100}$, which is much larger than the lifetime of the Universe, then the parallel computations can be, potentially, performed in the time of $(2^{300})^{1/4} = 2^{75} \approx 10^{25}$ steps. At the usual Gigabyte speed of 10^9 computational steps per second, this means $10^{25}/10^9 \approx 10^{16}$ seconds. Taking into account that there are approximately $3 \cdot 10^7$ seconds in a year, this means that the parallel computations would require
$$10^{16}/(3 \cdot 10^7) \approx 3 \cdot 10^8 = 300 \text{ million years},$$
still not very practical, but at least theoretically feasible.
- On the other hand, if computations on a sequential computer require $2^{600} \approx 10^{200}$ computational steps, then the parallel computations would require
$$10^{50}/(10^9 \cdot 3 \cdot 10^7) \approx 3 \cdot 10^{33} \text{ years},$$
still much larger than the lifetime of the Universe.

But what if we take into account that the space is actually multi-dimensional, of dimension $d > 3$? In this case, similar arguments lead to a better bound on $T_{\rm par}$:

$$T_{\rm par} \ge C \cdot T_{\rm par}^{1/(d+1)},$$

for some constant C. In particular, for $d = 10$, the sequential time of $2^{600} \approx 10^{200}$ seconds leads to the parallel time of $(10^{200})^{1/11} = 10^{22}$ computational steps, i.e., to

$$10^{22}/(10^9 \cdot 3 \cdot 10^7) \approx 3 \cdot 10^5 = 300\,000 \text{ years},$$

a more feasible time.

So, additional dimensions do help to speed up computations.

3 Let Us Summarize Our Findings

How can we resolve the first challenge: what is the physical meaning of extra dimensions? According to the proposed idea, extra dimensions – in line with the many-world interpretation of quantum physics – represent possible worlds. The main difference between this interpretation and the proposed idea is that in the proposed interpretation, we can use our free will to select one of the possible worlds – i.e., to move in these additional dimensions.

How can we resolve the second challenge: that we can affect the state of the universe, but no one's will was able to move any material object. The resulting explanation of this challenge is straightforward: yes, according to all the experiments so far, our will cannot change anything in the 3-D world, but probably what we can do is move between possible worlds – in other words, our free will can select in which of the possible worlds we will be in the future.

How we can resolve the third challenge: why are we smart. Why are we smarter than similar-size artificial networks? Maybe because the artificial neural networks live in the 3-dimensional space, while our brain can operate in the higher-dimensional space – and this increases our computational abilities.

Acknowledgments

This work was supported in part by the National Science Foundation grants 1623190 (A Model of Change for Preparing a New Generation for Professional Practice in Computer Science), and HRD-1834620 and HRD-2034030 (CAHSI Includes), and by the AT&T Fellowship in Information Technology.

It was also supported by the program of the development of the Scientific-Educational Mathematical Center of Volga Federal District No. 075-02-2020-1478, and by a grant from the Hungarian National Research, Development and Innovation Office (NRDI).

References

1. *Compatibilism*, Stanford Encyclopedia of Philosophy, https://plato.stanford.edu, downloaded on September 18, 2021.
2. F. Crick, *The Astonishing Hypothesis: The Scientific Search for the Soul*, Charles Scribner & Sons, New York, 1993.
3. P. Davies, *God and the New Physics*, Simon & Schuster, New York, 1983.
4. D. Dennett, *Elbow Room*, MIT Press, Cambridge, Massachusetts, 1984.
5. D. Dennett, *Freedom Evolves*, Viking Penguin, New York, 2003.
6. J. Earman, *A Primer on Determinism* D. Reidel, Dordrecht, Holland, 1986.
7. R. Feynman, R. Leighton, and M. Sands, *The Feynman Lectures on Physics*, Addison Wesley, Boston, Massachusetts, 2005.
8. J. M. Fischer, *God, Foreknowledge and Freedom*, Stanford University Press, Stanford, California, 1989.
9. H. Frankfurt, "Alternate possibilities and moral responsibility", *Journal of Philosophy*, 1969, Vol. 66, pp. 829–839.

10. I. Goodfellow, Y. Bengio, and A. Courville, *Deep Leaning*‘, MIT Press, Cambridge, Massachusetts, 2016.
11. M. B. Green, J. H. Schwarz, and E. Witten, *Superstring Theory*, Vols. 1, 2, Cambridge University Press, 1988.
12. J. Hospers, “What means this freedom?”, In: S. Hook (editor), *Determinism and Freedom in the Age of Modern Science*, Collier-Macmillan, New York, 1958, pp. 126–142.
13. W. Isaacson, *Einstein: His Life and Universe*, Simon and Schuster, New York, 2008.
14. R. Kane, *The Oxford Handbook of Free Will*, Oxford University Press, New York, 2002.
15. V. Kreinovich, A. Lakeyev, J. Rohn, and P. Kahl, *Computational Complexity and Feasibility of Data Processing and Interval Computations*, Kluwer, Dordrecht, 1998.
16. C. W. Misner, K. S. Thorne, and J. A. Wheeler, *Gravitation*, W. H. Freeman, New York, 1973.
17. D. Morgenstein and V. Kreinovich, “Which algorithms are feasible and which are not depends on the geometry of space-time”, *Geombinatorics*, 1995, Vol. 4, No. 3, pp. 80–97.
18. M. A. Nielsen and I. L. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press: Cambridge, U.K., 2000.
19. C. Papadimitriou, *Computational Complexity*, Addison-Wesley, Reading, Massachusetts, 1994.
20. R. Penrose, *The Emperor’s New Mind: Concerning Computers, Minds, and the Laws of Physics*, Oxford University Press, Oxford, UK, 2016.
21. R. Penrose, A. Shimony, N. Cartwright, S. Hawking, and M. Longair, *The Large, the Small and the Human Mind*, Cambridge University Press, Cambridge, Massachusetts, 2000.
22. J. Polchinski, *String Theory*, Vols. 1, 2, Cambridge University Press, 1998.
23. A. D. Sakharov, “Topological structure of elementary charges and CPT symmetry”, In: *Problems in Theoretical Physics, Dedicated to the Memory of I. E. Tamm*, Nauka, Moscow, pp. 243–247 (in Russian); English translation in *Collective Scientific Works of A. D. Sakharov*, Marcel Decker, New York, 1982.
24. S. Smilansky, *Free Will and Illusion*, Oxford University Press, New York, 2000.
25. P. Suppes, 11The transcendental character of determinism”, *Midwest Studies in Philosophy*, 1993, Vol. 18, pp. 242–257.
26. K. S. Thorne and R. D. Blandford, *Modern Classical Physics: Optics, Fluids, Plasmas, Elasticity, Relativity, and Statistical Physics*, Princeton University Press, Princeton, New Jersey, 2017.
27. F. J. Tipler, *The Physics of Immortality: Modern Cosmology, God and the Resurrection of the Dead*, Doubleday, New York, 1994.
28. J. Trusted, *Free Will and Responsibility*, Oxford University Press, New York, 1984.
29. J. C. Urenda and O. Kosheleva, “How to reconcile physical theories with the idea of free will: from analysis of a simple model to interval and fuzzy approaches”, *Proceedings of the IEEE World Congress on Computational Intelligence WCCI’2008*, Hong Kong, China, June 1–6, 2008, pp. 1024–1029.
30. P. Van Inwagen, *An Essay on Free Will*, Clarendon Press, Oxford, 1983.